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(54) Method of making a connecting rod for an internal combustion engine

(57) The method includes shaping a bundle (F) of uni-directional inorganic fibres, partially fusing the fibres to each other, positioning the bundle in a mould in such a manner to produce an extra gap for a predetermined machining allowance (*d*) between the bundle and mould wall. A molten light metal alloy is squeeze cast into the mould under high pressure, i.e., 500—2000 kg/cm³, forming an annular layer around the bundle. The rod portion of the obtained connecting rod is machined to final size (*b*) to remove defects, and takes the shape of a circular or elliptical cross-section.

F I G. 2

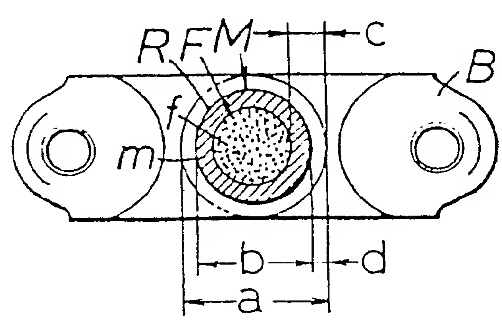

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FIG. 1

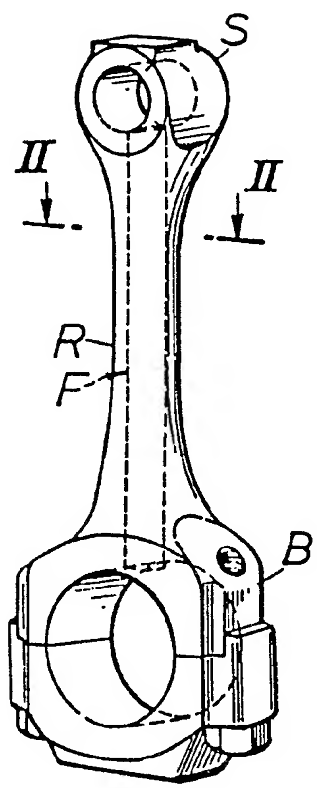


FIG. 3

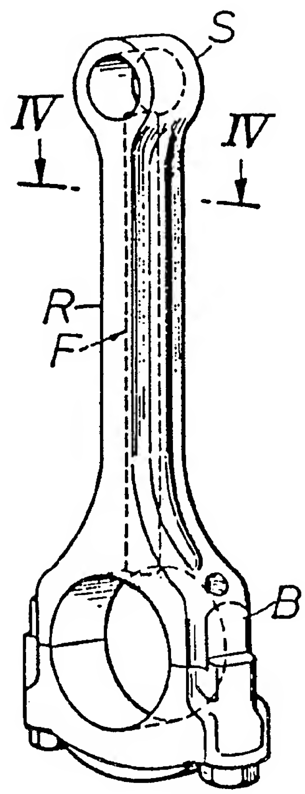


FIG. 2

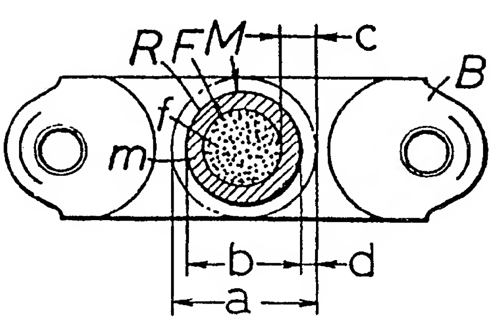
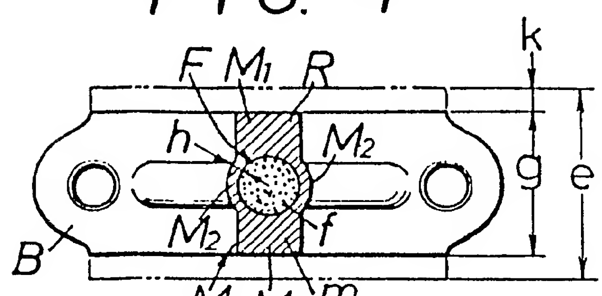


FIG. 4



SPECIFICATION
Method of making a connecting rod for an internal combustion engine

The present invention relates to a method of manufacturing a connecting rod for an internal combustion engine and more particularly to a method of manufacturing a connecting rod having a bundle of uni-directional inorganic fibres filled in and combined with a matrix of light alloy in the longitudinal centre portion of the rod.

Reference will first be made to Figures 3 and 4 of the accompanying drawings, in which:

Figure 3 is a diagrammatic perspective view of a connecting rod made in accordance with a previously proposed method; and

Figure 4 is a cross-sectional view taken along line IV—IV of Figure 3.

The fibre-reinforced connecting rod shown in Figures 3 and 4 has been previously proposed and comprises a small annular end portion, a large annular end portion B and a rod portion R connecting the small and large annular end portions.

The rod portion R has a core made of a bundle of uni-directional inorganic fibres filled in and combined with a light alloy matrix, and a single component matrix portion formed outside of the core. The small end portion can be considered to have a central axis. In a cross-sectional view of the rod portion R in Figure 4, the single component matrix portion includes a pair of rectangular portions M_1 formed along the central axis of the small end portion in such a manner as to sandwich the core of fibres and alloy and a pair of arc-shaped portions M_2 formed between the rectangular portions M_1 and also sandwiching the core of fibres and alloy. Notches are formed between the rectangular portions and the arc-shaped portions. The concentration of stress is higher at the notches and, therefore, a factor of stress concentration is relatively increased. The single component matrix portion is made by squeeze casting and, therefore, the strength of the rod portion is higher than other general cast articles. However, it has been found in a fatigue test that the single component matrix portion was inclined to have an initiation of a fatigue crack. The crack extended all over the single component matrix portion to surround the core of the bundle of fibres. Finally, it caused a premature fatigue failure. It has been found further that when such a single component matrix portion had a defect in casting, for example, a mixing of oxidated substance, a blow-hole, etc., the fatigue strength was liable to be variable. As a result, the lifetime of the single component matrix portion could not be kept constant or predicted.

A connecting rod made in accordance with the previously proposed method is made as follows:—

A bundle of 65,000 stainless steel fibres (SUS 33 in accordance with Japanese Industrial Standards (JIS)) each having an outside diameter of 25 microns is prepared and inserted into a heat resistant tube. The tube could not be made, for example, of silica glass. The shape of the cross-section of the tube is circular. The bundle of stainless steel fibres are heated at 700°C for ten minutes. In this manner, the stainless steel fibres are partially fused together. That is, at the points where the different fibres touch each other, they are fused or welded together. The temperature of about 700°C is critical because if the fibres are heated at a higher temperature, the fibres lose their strength. The diameter of the round cross-section is 9.5 mm. The bundle is 128 mm long. The bulk density is 3.5 grams/cc.

A mould is prepared having a ram-up core for forming the small diameter annular end portion and a ram-up core for forming the large diameter semi-annular end portion.

The uni-directional bundle of inorganic fibres as prepared above is laid within previously prepared concave portions of the mould between the ram-up cores as a bridge.

Using an aluminium alloy (AC4D in accordance with Japanese Industrial Standards (JIS)) as the matrix, the alloy is filled into the uni-directional bundle of inorganic fibres and squeeze cast to produce the connecting rod. Following casting, both side face surfaces of the connecting rods of both are machined to remove the material K shown in Figure 4. The machining is done to ensure that the faces of the large diameter semi-annular end portion and the small diameter annular end portion are parallel with each other and perpendicular to the axis of the openings.

Table I shows the characteristics and material after machining of the end portions:

Table I

	Before machining	*After machining*
Width e or g shown in Figure 4 of connecting rod	33.8 mm (e of Figure 4)	21.8 mm (g of Figure 4)
Cross-sectional area of rod portion	331.7 mm²	218.9 mm²
Volume fraction $\overline{V}_f$ of fibre bundle of rod portion	—	14.6%
Gap between the wall of the mould cavity and the fibre bundle prior to casting	2 mm (h of Figure 4)	—
Cutting area for machining	6 mm (k of Figure 4)	—

According to the present invention, there is provided, a method of making a connecting rod for an internal combustion engine, the rod having a small annular end portion, a larger end portion, and a rod portion therebetween, the rod portion having a longitudinal axis, the method comprising the steps of:

shaping a bundle of inorganic reinforcing fibres, placing the bundle in a mould, the mould having cavities to form the annular end portion and rod portions, the bundle being placed along the longitudinal axis of the rod portion, the mould being sized such that a predetermined gap exists between the bundle and the cavity for the rod portion, squeeze casting a molten light metal alloy into the mould forming a matrix annular layer of the alloy around the bundle in said gap, machining the matrix annular layer to a predetermined shape and removing a predetermined machining allowance.

The connecting rod so obtained includes a bundle of uni-directional inorganic fibres filled in and combined with the matrix and a single component matrix annular layer surrounding the bundle having a sufficient predetermined machining allowance. The sufficient predetermined machining allowance is added to the gap between the bundle and the wall of the cavity of the mould and enables a smooth-flow of the molten light metal alloy in the mould. The tendency for cold shut is thereby reduced and the filling performance of the molten metal into the bundle of uni-directional inorganic fibres is improved. The squeeze casting can comprise the steps of applying a hydrostatic high pressure of 500—2000 kg/cm^2 to a molten light metal alloy poured into a mould and solidifying the molten metal under such high pressure. A part of or the entire single component matrix annular layer is thereafter machined so that the portion where there is a tendency for the initiation of fatigue cracks or where there is any other defective portion in casting is reduced and removed. It would be desirable to eliminate any possibility of the initiation of a fatigue crack by machining away the entire single component matrix annular layer thereby exposing the core bundle of uni-directional inorganic fibres. However, this could result not only in a difficulty of machining and interfacial separation of reinforcing fibres, but also in a decrease of strength of the rod portion. Therefore, the single component matrix annular layer is generally only partially cut away. Moreover, a connecting rod having a circular or elliptical shape in cross-sectional view of the rod portion is easily obtained by machining the single component matrix annular layer. In this manner, the factor of stress concentration of the matrix annular layer can be decreased and also the fatigue limit can be improved.

For a better understanding of the invention and to show how the same may be carried into effect, reference will now be made, by way of example, to the accompanying drawing, in which:—

Figure 1 is a diagrammatic perspective view of a connecting rod made in accordance with the present invention, and

Figure 2 is a cross-sectional view taken along line II—II of Figure 1.

A connecting rod made in accordance with the present invention is shown in Figures 1 and 2. It is produced as follows:

A bundle of 65,000 stainless :steel fibres (SUS 33 in accordance with Japanese Industrial Standards (JIS)) each having an outside diameter of 25 microns is prepared and inserted into a heat-resistant tube. The tube could be made, for example, of silica glass. The shape of the cross-section of the tube is a circular shape. The bundle of stainless steel fibres are heated at 700°C for ten minutes. In this manner, the stainless steel-fibres are partially fused together. That is, at the points where the different fibres touch each other, they are fused or welded together. The diameter of the round cross-section is 11 mm. The bundle is 128 mm long. The bulk density is 2.62 g/cc.

A mould for forming the connecting rod is prepared having a first ram-up core for forming the small diameter annular end portion and a second ram-up core for forming the large diameter semi-annular end portion. The uni-directional bundle of inorganic fibres prepared above is laid within previously prepared concave portions of the mould between the ram-up cores as a bridge.

Using an aluminium alloy (AC4D in accordance with Japanese Industrial Standards (JIS)) as the matrix metal m, the molten metal alloy is filled into the uni-directional bundle of inorganic fibres and squeeze cast to produce the connecting rod having a predetermined machining allowance.

After that, the rod-shaped portion of the connecting rod is machined and the connecting rod having the rod-shaped portion R with a circular cross-section (Figure 2) is obtained.

The rod-shaped portion R of this connecting rod has its centre occupied and reinforced by a uni-directional bundle of inorganic fibres aligned along the longitudinal axis of the rod portion, with the bundle of inorganic fibres being filled and compounded by the light metal alloy matrix, and a light metal alloy matrix layer having a predetermined machining allowance around the core.

Table II shows the characteristics of the rod portions before machining and after machining:

Table II

	Rod portion before machining	*Rod portion after machining*
Diameter	20.5 mm (a of Figure 2)	16.5 mm (b of Figure 2)
Cross-sectional area	329.9 mm^2	213.7 mm^2
Volume fraction $\overline{V}_f$ of this bundle	—	14.9%
Gap between the wall of the mould cavity and the fibre bundle prior to casting	4.75 mm (c of Figure 2)	—
Allowance	2 mm (d of Figure 2)	—

As can readily be understood from a comparison of Tables I and II, the gap of the present invention between the uni-directional bundle of inorganic fibres and the sidewall of the cavity of the mould is wider than in the previously proposed method. Therefore, the running performance of molten metal is simplified, and this reduces the tendency of cold shut. Additionally, the filling and compounding performances of the matrix are very good.

A stress-concentration factor, average fatigue limit at room temperature and standard deviation of said fatigue limit at room temperature between the connecting rod of the present invention and the connecting rod produced by the previously proposed method are shown in the following Table III:

Table III

	Present invention	*Previously proposed method*
Stress-concentration factor	1.0	1.35
Average value of fatigue limited	15.1 kg/mm^2	11.2 kg/mm^2
Standard deviation of fatigue limit	1.1 kg/mm^2	1.5 kg/mm

As can be readily understood from Table III, stress-concentration factor is (1.0) in the present invention. This value means that the cross-sectional area of rod-shaped portion is round in shape and so a stress-concentration part does not exist.

Therefore, the average fatigue limit is increased and its standard deviation was improved. This means that the reliability of this connecting rod became high.

In the present invention, the purposeful provision of the predetermined machining allowance around the rod portion has the advantage that a larger gap is used in the mould. This enables the molten metal to flow smoothly between the mould cavity wall and the uni-directional bundle of inorganic fibres. Molten metal running performance is good and cold shuts are prevented. The molten metal matrix is filled into the uni-directional bundle smoothly.

It is possible to eliminate or significantly decrease the problems of defects of casting and fatigue crack initiation part by machining the surface of the light metal alloy matrix layer. In this manner, the fatigue limit is increased and it becomes possible to predict the lift of the connecting rod and a reliable connecting rod is produced.

Claims

1. A method of making a connecting rod for an internal combustion engine, the rod having a small annular end portion, a larger end portion, and a rod portion therebetween, the rod portion having a longitudinal axis, the method comprising the steps of:

shaping a bundle of inorganic reinforcing fibres, placing the bundle in a mould, the mould having cavities to form the annular end portion and rod portions, the bundle being placed along the longitudinal axis of the rod portion, the mould being sized such that a predetermined gap exists between the bundle and the cavity for the rod portion, squeeze casting a molten light metal alloy into the mould forming a matrix annular layer of the alloy around the bundle in said gap, machining the matrix annular layer to a predetermined shape and removing a predetermined machining allowance.

2. A method as claimed in Claim 1, wherein the step of shaping the bundle includes forming the bundle from a plurality of uni-directional inorganic fibres, placing the bundle in a heat-resistant shaping container and heating the container bundle at least partially to fuse the inorganic fibres to each other.

3. A method as claimed in Claim 1 or 2, wherein the step of squeeze casting includes applying a hydrostatic high pressure of from substantially 500 to substantially 2000 kg/cm^2 to a molten light metal alloy poured into the mould and solidifying the molten light metal alloy under such high pressure.

4. A method as claimed in Claim 2 or in Claims 2 and 3, wherein the heating step is at a temperature of 700°C.

5. A method as claimed in any one of the preceding claims, wherein the bundle is shaped to have a circular cross-section.

6. A method of making a connecting rod for an internal combustion engine, substantially as hereinbefore described with reference to Figures 1 and 2 of the accompanying drawings.

7. A connecting rod as made by the method as claimed in any preceding claim.

8. A connecting rod as claimed in Claim 7, substantially as hereinbefore described with reference to Figures 1 and 2 of the accompanying drawings.

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